

Experimental Investigation of Supersonic Coplanar Jets within Ejectors

Final Report

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This experimental and theoretical work involved reduction of supersonic jet noise using Mach Wave Elimination (MWE), a method that suppresses noise by means of a gaseous layer that envelops the supersonic jet. Also explored was a new method for mixing enhancement in which an axial, secondary flow enhances mixing in a primary flow. The research is relevant to the advent of future supersonic transports that must adhere to the same take-off and landing restrictions as ordinary subsonic aircraft. To reduce noise, one needs to understand the fundamental fluid mechanics of the jet, namely its turbulent structure and mean-flow characteristics, and to perform high-quality noise measurements. The results generated are applicable to free jets as well as to jets within ejectors.

Noise Reduction

- Mean flow characteristics of high-speed jets: Addition of a secondary flow around a jet changes significantly its mean flow characteristics and elongates the noise source region. Experiments have measured the mean velocity field of coaxial jets and models for the potential core length and noise source regions have been developed¹.
- Targeted Mach Wave Elimination: In this implementation of MWE, the coflow is applied only on the lower side of the jet. The benefits are a shorter noise source region (because the jet maintains its natural growth rate) and a smaller amount of secondary flow. The resulting noise suppression in the downward direction (towards the ground) is substantial, as much as 18 decibels, while the upward sound field (towards the sky) stays the same. This is the first work to demonstrate directional suppression of sound from a jet; also, it is the first work to show reduction of crackle (an annoying component of noise arising from the nonlinearity of pressure waves) using a coflow^{2,3}.
- Theoretical model for Mach wave elimination: A simple linear model captures the salient physical elements of the technique and forms the basis for

more elaborate treatments. An experiment using a small rectangular jet with variable-height coflow was used to confirm the theoretical trends ⁴.

- Engine cycle analysis :A preliminary analysis of the Brayton cycle indicates that a turbofan engine with jet and coflow conditions for Mach wave elimination is feasible using current technologies. Engines for supersonic business aircraft that apply this method could be designed around the core of current military turbofan engines⁵.

Mixing Enhancement

Mixing Enhancement using Axial Flow (MEAF) is the generic name of a phenomenon discovered in experiments on coaxial jets. It involves use of an axial flow and special nozzle configurations to enhance the spreading rate the flow itself (Jet Self Excitation - JSE) or of an adjacent flow (Mixing Enhancement via Secondary Parallel Injection - MESPI). Applications include enhancing fluid mixing within an ejector and thermal signature reduction from aircraft engines. The advantage over conventional techniques is use of an axial flow (i.e., a source of thrust) to promote instability, versus transverse flow or even reverse flow used by existing fluidic devices. Also, the nozzle shapes are clean and simple, instead of complex and heavy mixers used today. Experiments have demonstrated the occurrence of this instability in a variety of nozzles, axisymmetric and rectangular, and have mapped out the range of nozzle pressure ratios under which it occurs⁶.

The following publications have resulted from grant NAG-1-2104 and are appended to this summary:

1. Murakami, E., and Papamoschou, D., "Mixing Layer Characteristics of Coaxial Supersonic Jets" AIAA-2000-2060, presented at the 6th AIAA/CEAS Aeroacoustics Conference, 12-14 June, 2000, Maui, Hawaii.
2. Papamoschou, D., and Debiase, M., "Targeted Mach Wave Elimination," AIAA-2000-0085, presented at the AIAA 38th Aerospace Sciences Meeting, January 2000, Reno, Nevada.
3. Papamoschou, D., and Debiase M., "Directional Suppression of Noise from a High-Speed Jet," AIAA Journal, Vol. 39, No.3, 2001, pp. 380-387.
4. Papamoschou, D., "Linear Model for Mach Wave Suppression in a Dual-Stream Jet," AIAA-2000-2062, presented at the 6th AIAA/CEAS Aeroacoustic Conference, 12-14 June, 2000, Maui, Hawaii.
5. Debiase, M., and Papamoschou, D., "Application of the Mach Wave Elimination Method to Supersonic Jet Engines, " presented at the 14th International Symposium on Airbreathing Engines (XIV ISABE), September 1999, Italy.
6. Papamoschou, D., "Mixing Enhancement Using Axial Flow," AIAA-2000-0093, presented at the AIAA 38th Aerospace Sciences Meeting, 10-13 January 2000, Reno, Nevada.